Research article

Effects of Stubble Mulching on Plant Growth of Pearl Millet and Soil Moisture Condition

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Abstract Sub-Saharan Africa is one of the most vulnerable regions, as desertification has been advancing. In order to mitigate the degradation of crop productivity, this study aims to investigate how to apply pearl millet stalk residues for improving soil moisture condition and plant growth. The experiment was carried out at a greenhouse of Tokyo University of Agriculture, Japan. Pearl millet (*Pennisetum glaucum* (L.) R. Br.) was cultivated at each plot of 6.5 m long and 0.8 m wide, and soil moisture was monitored with a TDR soil moisture meter. Nine plots were divided into 3 groups based on irrigation intensity; the first was irrigated at 3 to 6 mm/day as standard plots, the second at 2/3 of the standard as slightly water-saving plots and the third at 1/3 of the standard as water-saving plots. Each group was constituted with 3 different treatments; stubble mulching with pearl millet stalk residues, mixing soil with pearl millet stalk residues and non-treatment as control. The results from non-treatment indicated that plant growth of pearl millet above ground surface did not show a significant difference among the plots under the different irrigation intensities. Under non-treatment condition, pearl millet even in the 2/3 and 1/3 water-saving plots grew as well as that in the standard plots. However, the fresh weights of non-treatment were significantly lower than that of other treatments, stubble mulching or mixing soil with pearl millet stalk residues, at 95% confidence level. Additionally, there was a tendency for pearl millet growth of stubble mulching to be higher than that of mixing soil with pearl millet stalk residues. This implies that mulching with pearl millet stalk residues can be more effective for plant growth. The utilization of stubble mulching in the production of crops under low rainfall condition such as Sub-Saharan Africa is expected to play beneficial roles such as improving soil moisture condition and plant growth.

Keywords stubble mulching, soil moisture, pearl millet, Sub-Saharan Africa

INTRODUCTION

Sub-Saharan Africa (hereinafter, SSA) is increasing the annual percentage rate of population at 2.3% (UNFPA, 2008). SSA is one of the most hazardous regions as desertification has been advancing severely, and higher than 35% of total population is undernourishment at 16 countries (WFP, 2009). Especially, the amounts of annual precipitation in West African countries bounding the Sahara in SSA are less than 500 mm (FAO, 2000), in addition to the insufficient nutrient of soil. Therefore, it is difficult to irrigate sufficiently for crop production with limited water resources.

However, it is a global issue for corresponding to the world food security and soaring of food price. Improvement of agricultural productivity is just urgent theme in SSA. In order to rehabilitate

soil and water environment for crop growing, Kobayashi et al. were verified in 2009 that mulching with organic matters was effective for reducing evaporation from soil moisture. Particularly for the growth of the upland rice, the effect of mulching at both early growth and heading promotion was remarkably noticed.

However, recent research attention has been paid to pearl millet (*Pennisetum glaucum* (L.) R. Br.), which is one of the most popular cereal crops in SSA. So, this study aims to investigate the effects of stubble mulching with pearl millet stalk residues on pearl millet growth comparing with that of mixing soil with pearl millet stalk residues or non-treatment as control. The terminology of stubble mulching in this study means a soil covering system utilizing crop residues existed already in site.

MATERIALS AND METHODS

The experiment was carried out at the greenhouse of Tokyo University of Agriculture from May to October, 2009. Pearl millet was cultivated on each plot of 6.5 m long and 0.8 m wide (Fig.1). Nine plots were divided into 3 groups based on irrigation intensity; the first was irrigated at 3 to 6 mm/day as standard plots, the second at 2/3 of the irrigation amounts of standard plots as slightly water-saving plots and the third at 1/3 of the amounts of standard plots as water-saving plots. Each group was constituted with 3 different treatments; stubble mulching with pearl millet stalk residues, mixing soil with pearl millet stalk residues and non-treatment as control. Regarding stubble mulching, air-dried pearl millet stalk residues were cut at approximately 3 cm in length and arranged for covering soil in the plots. Also, air-dried and cut pearl millet stalk residues were applied for mixing with soil at a depth from 0 cm to 5 cm. Nothing was applied for non-treatment. Same amounts of pearl millet stalk residues at 2 kg was applied in each plot of stubble mulching or mixing treatment, and after 30 days the germinated pearl millet was transplanted zigzag in each plot at the interval of 0.8 m vertically and 0.2 m horizontally, approximately. Certain amounts of water were irrigated at 2 to 3 days interval. The irrigation amounts of standard plots were the same as that of standard cultivation of upland rice in Japan, and the irrigation amounts of 2/3 or 1/3 water-saving plots were estimated on the basis of the precipitation in Sahel-Sudan climate zone or Sahel climate zone, respectively.

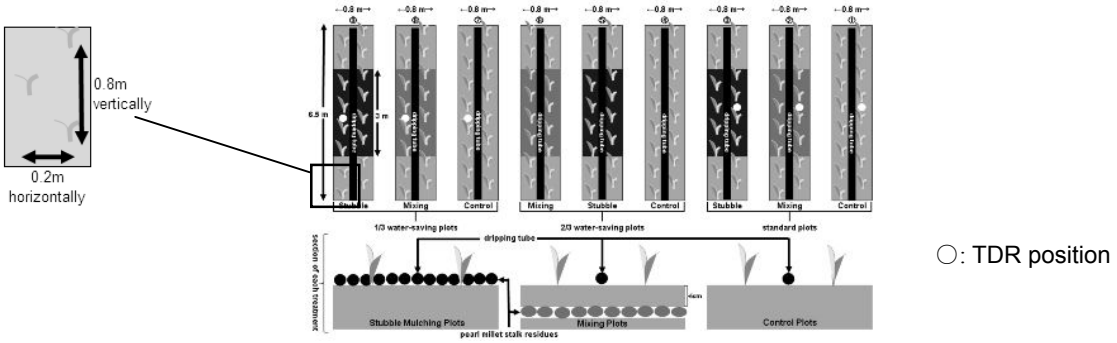


Fig. 1 Schematic diagram of the cultivation experiments and the section of each treatment

Fig. 2 Stubble mulching

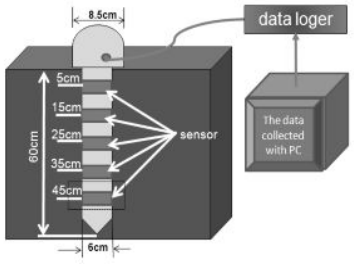


Fig. 3 Outline of the TDR system

Soil moisture was measured at certain interval with TDR to observe the changes in soil moisture. TDR has devices for accurate measurement of reflected electromagnetic signals (Or, O., and Wraith, J. M., 2000). The interval measuring soil moisture was 1 hour using SMART-Enviro (Sentek Pty, Ltd. 2005) with 5 TDR sensors (5 cm, 15 cm, 25 cm, 35 cm and 45 cm deep) as shown in Fig.3.

RESULTS AND DISCUSSION

Water was provided by drip irrigation method at 2 to 3 days interval. Among standard plots, the fluctuation of volumetric water content in the plot of stubble mulching was remarkably less than that of non-treatment as control (Fig.4).

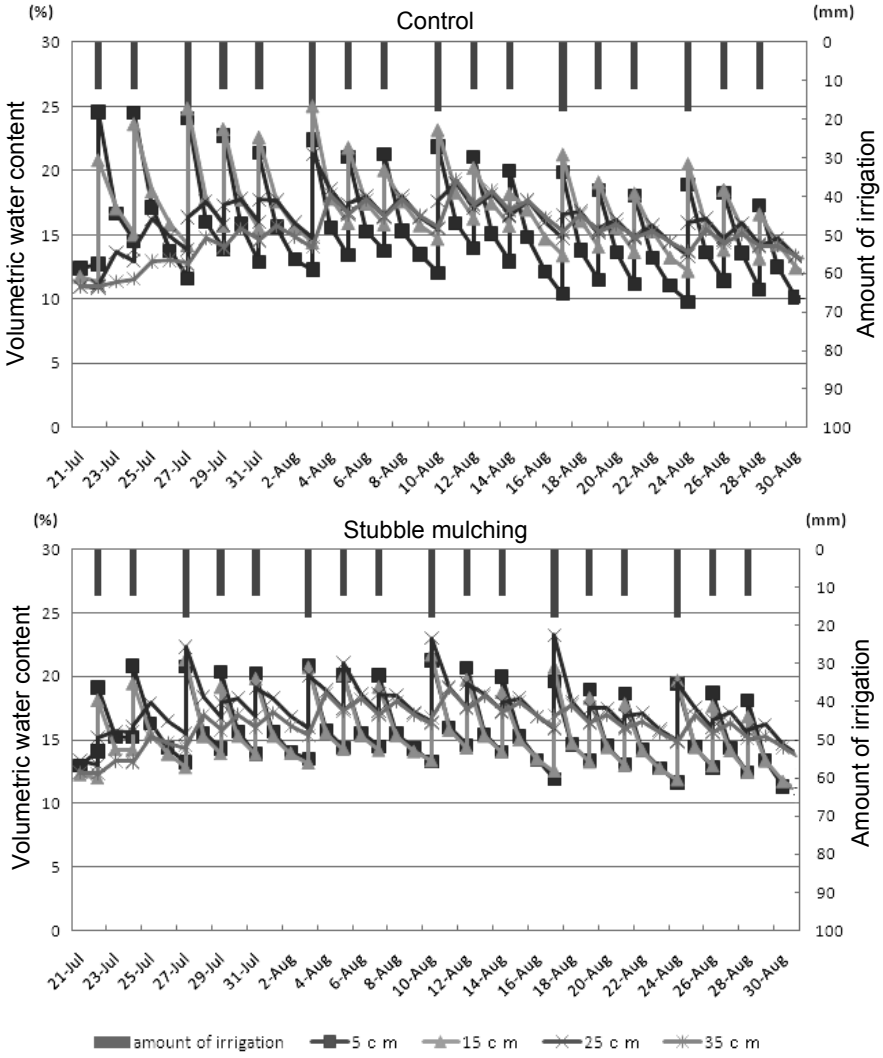


Fig.4 Changes in volumetric water content among standard plots

Regarding the growth of pearl millet, the plant height was measured periodically every 20 days from the third day of transplanting, also various plant weights of fresh, dry and spike ones were measured at the harvesting period. From the results of standard plots irrigated at 3 to 6 mm/day, there was a tendency for the plant heights of mixing soil with pearl millet stalk residues to be slightly higher than that in other treatments. However in the 1/3 water-saving plots, remarkable difference was not

observed among the treatments; stubble mulching, mixing soil with pearl millet stalk residues and non-treatment as control (Fig. 5).

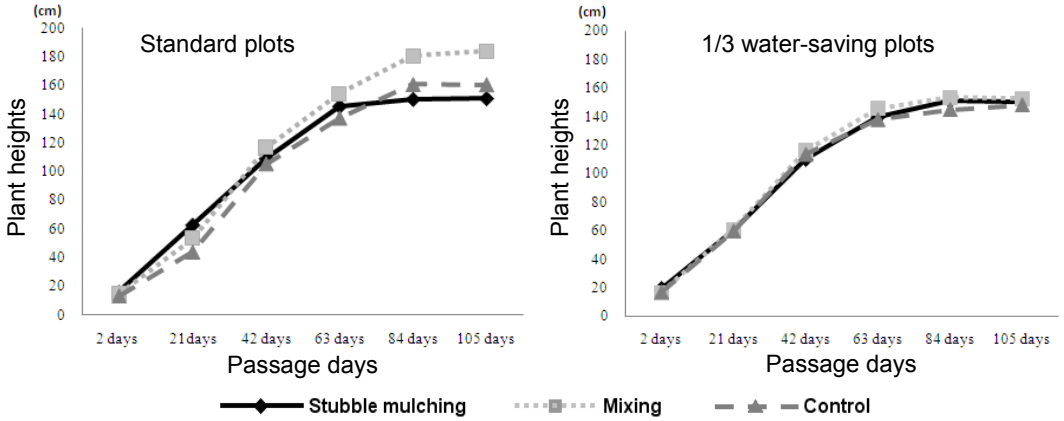
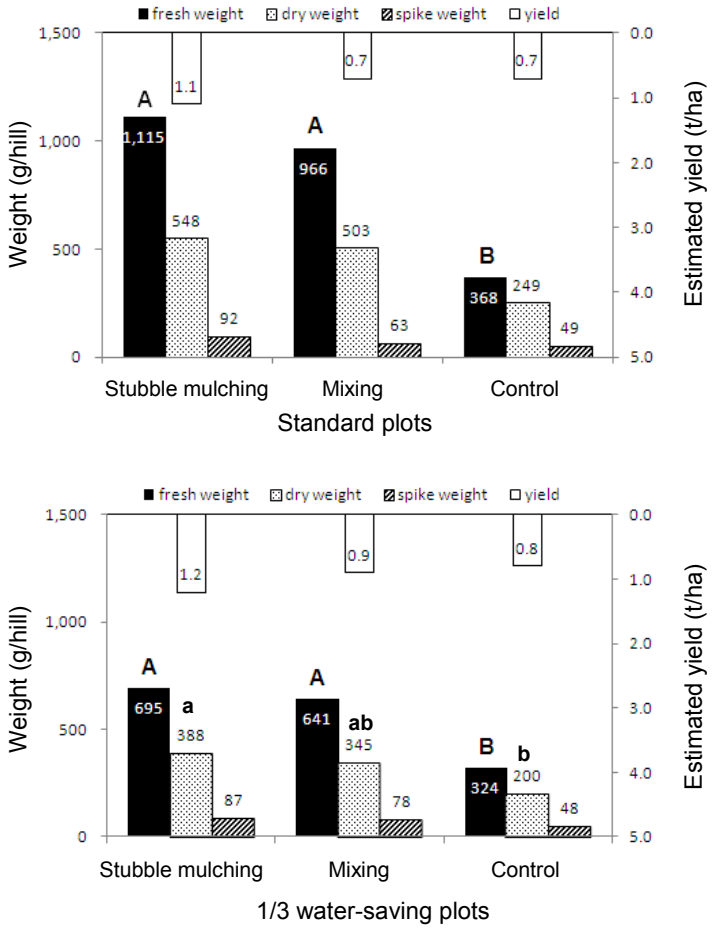


Fig.5 Changes in plant heights after transplanting

However, at both standard plots and 1/3 water-saving plots, there were tendencies for fresh, dry and spike weights in the plots of stubble mulching or mixing soil with pearl millet stalk residues to be remarkably higher than that of control (Fig.6).



**The data followed by different letters differs significantly at 95% confidence interval based on one-way factorial ANOVA analysis.*

Fig.6 Comparison of pearl millet growth under different treatments

Especially, the fresh weights of control at both standard plots and 1/3 water-saving plots were significantly lower than that of other treatments, stubble mulching or mixing soil with pearl millet stalk residues, at 95% confidence level based on one-way factorial ANOVA analysis (Fig.6). Additionally, there was a tendency for pearl millet growth in the plots of stubble mulching to be higher than that of mixing soil with pearl millet stalk residues, although a significant difference at 95% confidence level was not recorded.

Additionally, the yields under stubble mulching converted to the amounts per hectare were 1.1 t/ha and 1.2 t/ha for standard and 1/3 water-saving plots, respectively (Fig.6). It means the experimental results indicated approximately 2 times higher than the average yield at 0.451 t/ha of the Republic of Niger in FY2007 (Himeno et al, 2009).

CONCLUSION

This study dealt with the comparison in pearl millet growth among 3 different treatments as stubble mulching with pearl millet stalk residues, mixing soil with pearl millet stalk residues and non-treatment as control under 3 different irrigation intensities; the first was irrigated at 3 to 6 mm/day as standard plots, the second at 2/3 of the irrigation amounts of standard plots as slightly water-saving plots and the third at 1/3 of the amounts of standard plots as water-saving plots. The irrigation amounts of 2/3 or 1/3 water-saving plots were estimated on the basis of the precipitation in Sahel-Sudan climate zone or Sahel climate zone, respectively.

The results from non-treatment indicated that plant growth in pearl millet above ground surface did not show a significant difference among the plots of different irrigation amounts. However, the fresh weights of control at both standard plots and 1/3 water-saving plots were significantly lower than that of other treatments as stubble mulching or mixing soil with pearl millet stalk residues at 95% confidence level. Additionally, there was a tendency for pearl millet growth in the plots of stubble mulching to be higher than that of mixing soil with pearl millet stalk residues, although a significant difference at 95% confidence level was not recorded.

Accordingly, it was concluded the utilization of stubble mulching in the production of crops under low rainfall condition such as Sub-Saharan Africa is expected to play beneficial roles such as improving soil moisture condition and plant growth.

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REFERENCES

FAO (2000) Sahel Weather and Crop Situation Report, No.1.

Himeno, K., Inoue, N., Ito, O., Kobayashi, Y., Kurauchi, N. and Nishikawa, Y. (2009) Minor cereals in Niger, Focusing on pearl millet and sorghum, Tropical Crops Handbook, Japan Association for International Collaboration of Agriculture and Forestry.

Kobayashi, Y., Yato, S., Fujikawa, T., Nakamura, T., Mihara, M. and Komamura, M. (2009) Study on Stable Mulching as Effective Water Saving Practice, Journal of Arid Land Studies, 19(1), 309-312.

Or, O. and Wraith, J.M. (2000) Soil Water Content and Water Potential Relationships, Handbook of Soil Science, A53-85.

Sentek Pty, Ltd. (2005) SMART-Enviro, Japanese Edition Manual, TWC.

UNFPA (2008) State of World Population, United Nations Population Fund.

WFP (2009) http://www.wfp.or.jp/hungermap/, 2009/10/12.